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1083-224

WRIGHT AIR DEVELOPMENT CENTER

AIR RESEARCH AND DEVELOPMENT COMMAND

WRIGHT-PATTERSON AIR FORCE BASE, OHIO

IN REPLY ADDRESS BOTH COMMUNICATIONS AND ENVELOPE TO COMMANDER, WRIGHT AIR DEVELOPMENT CENTER, ATTENTION FOLLOWING OFFICE SYMBOL:

WCLRE5

2 JUL 1957

SUBJECT: Transmittal of Report

TO: Lincoln Laboratories
ATTN: Dr. F. Rodgers
Lexington, Mass

1. The inclosed report is transmitted for your reference and retention per the request of Major White of Hq ARDC Baltimore, Md.

2. This paper was prepared by W.F. Bahret of this Center. Any additional information required will be supplied upon request.

FOR THE COMMANDER:

Charles N. Keller
CHARLES N. KELLER
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Aerial Reconnaissance Laboratory

1 Incl:
Rpt, N/D, Test
Outline for "Passport
Visa"(1cy)(57WCLR-3116)
(S)

IF ENCLOSURES ARE ... (OR NOT ATTACHED) THE CLASSIFICATION OF THIS CORRESPONDENCE WILL BE CANCELLED IN ACCORDANCE WITH PAR. 28, AFR-205-1.

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Test Outline for "Passport Visa"

For the past several years, the Wave Propagation Section of the Aerial Reconnaissance Laboratory, WADC, has been developing a radar absorber material suitable for structural application to aircraft. This work has been carried on under Project 6268, Task 40542, "Radar Camouflage Study."

Laboratory measurements have established the characteristics of the absorber when formed in simple shapes of fairly small dimensions. However, size limitations prevent the determination of the effect of the absorber on large complex shapes such as aircraft. At the moment, the only way to perform such an evaluation is through the use of a flying test bed and appropriate radar equipment to determine the degree of absorption under dynamic conditions. Inasmuch as the material arrived at a stage of development where such a test would be extremely beneficial, ARDC was requested to assign an aircraft for this purpose. Accordingly, a T-33 aircraft was assigned and the effort given the nickname "Passport Visa." The purpose of this paper is to give a general outline of the types of testing to which the aircraft will be subjected and the goal in each type.

Laboratory tests have shown that the absorber reflects less than 5% of the incident energy (compared to 100% for metal) over the frequency range 2500 to 13000 mc inclusive. It is very insensitive to angle of incidence of the energy. It is desired to perform the dynamic tests at as many frequencies as reasonably possible over the operating range of the material.

The T-33 aircraft is to be completely covered with the absorber with the exception of part of the canopy and the engine intake and exhaust ducts. Thus, tests can be performed at all aspects of the aircraft. The actual installation of the absorber on the aircraft is estimated to be completed by approximately 1 January 1958. The radar reflectivity testing will begin as soon thereafter as possible.

Many portions of the T-33 will be covered with the material in such a way that the absorber can be removed and replaced by other material. This is done so that any im-

provements in the absorber yielded by a simultaneous development effort can also be evaluated dynamically. It is anticipated that this dynamic test program will continue for 1 1/2 to 2 years after completion of the initial installation.

In order to simplify the measurements and to require minimum modification to existing equipments, it is proposed that the reflectivity data be taken on a relative basis rather than an absolute basis. That is to say, the reflection from the absorber-coated T-33 will always be compared to that from an uncoated T-33 which will be flown either simultaneously with, or within a short period of the coated aircraft. This will eliminate the need for absolute calibration of the radar equipment and its associated problems.

The reflectivity tests will be designed to provide one or more of the following types of information:

a. Relative detection range for the two aircraft as a function of aspect angle.

b. Relative echo signal intensity as a function of aspect angle.

c. Degradation of defensive system performance due to use of the absorber.

d. Relative effectiveness of improved absorber materials.

e. Effect of partial coating on reflectivity.

To date, several agencies have been contacted regarding the availability of radar gear in the proper frequency range for making these measurements, and the types of measurements which can be performed. These agencies are WADC, RADC and the 58th. Air Division (Air Defense Command group stationed at W-PAFB). A summary of the types of equipment turned up by the survey thus far follows (see Appendix 1 for pertinent characteristics):

<u>WADC</u>

APS-20	"S" band search radar
MSQ-1	"S" band tracking radar
APS-44A	"C" and "X" band search radar

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WADC (continued)

FPS-16	"X" band precision approach radar
FPS-6	"S" band height finder radar
APG-37	"X" band airborne fire control radar

RADC

TPS-16	"S" band airport surveillance radar
SCR-584	"S" band tracking radar
MSQ-1A	"S" band tracking radar
MPS-4	"C" band height finder radar
TPS-10D	"X" band height finder radar
MPS-14	"S" band height finder radar

58th. Air Division

FPS-10	"S" band search radar
FPS-6	"S" band height finder radar

Several types of airborne fire control radar.

Virtually all of the above radars could be used to supply information on relative detection range without any modification having to be performed. Since the aircraft is to be based at WADC and has a limited flying range, it would be advantageous to conduct these tests on the gear at or near W-PAFB.

None of these radars is currently instrumented to record the echo signal intensity. Such recording would require some modification in any case in order to provide a wide dynamic range in the receiving equipment. The tracking radars do have an AGC voltage which is proportional to the echo amplitude, and would require a minimum of modification to record it. This AGC voltage, however, is slow-acting and, while it would yield the average echo level as a function of time, would not permit the recording of any rapid fluctuation in echo from the aircraft. Such data would provide the relative levels of the average echo intensity from the two aircraft, if properly calibrated, and is

therefore desirable. Unfortunately, only "S" band information could be supplied in this manner since no higher frequency tracking radars were found in the survey. To get this type of data from any of the higher frequency gear, fairly elaborate modifications would have to be performed to provide the dynamic range necessary. Personnel at WADC associated with "Passport Visa" have made such modifications to radar systems in the past to perform absolute dynamic measurements. Personnel at the other agencies contacted indicated that such modifications would be made only if directed by higher headquarters and provided with considerable assistance by WADC personnel experienced in such matters. It is again therfore desireable to perform such tests at W-PAFB.

The procedure for determining the relative detection range for the two aircraft is shown in Fig. 1 and 2. Fig. 1 shows the flight paths of the two aircraft for nose and tail data. The aircraft would be positioned in space so as to fly through the marginal detection range of the radar while alternately presenting the nose and tail aspect to the radar. The absorber-coated aircraft would be flown at approximately half the range of the standard aircraft, this being the assumed range of marginal detection. This is done in order to conserve fuel since the coated aircraft can only fly for approximately one hour. Due to the wide variation in detection range for the various radars which will be used in these tests, no fixed values of range can be given for the two aircraft. Rather it appears advisable to fly the uncoated T-33 out to determine its detection range and then adjust the coated T-33 flight path so as to include its probable detection range. In the event that the range for the coated T-33 would be so short that, when flying at the same altitude as the standard, it would present a very different aspect to the radar, its altitude would be reduced to get the same aspect (see Fig. 3).

Essentially the same type of plan would be used to secure breadside data (see Fig. 2). The flight plan shown will gradually move the aircraft in range while permitting it to be broadside to the measuring radar most of the time. Thus, the range at which marginal detection takes place can again be determined.

In practically all cases, the radar antenna will be scanned horizontally to avoid the necessity of the pilot's having to fly within the beam limits of a fixed antenna. It would be desirable to sector scan the area in which the aircraft will be located, but mechanical limitations of some of the larger antennas will necessitate scanning 360 degrees. This is not felt to be too serious a problem.

The problem of aiming the antennas in the vertical plane varies with the type of radar used. The simplest case is that of a standard search or surveillance radar which has a fan-shaped beam in the vertical plane. Obviously, no aiming is required in this case. The next simplest is the height finder which nods vertically, thus effectively scanning the range of elevation angles of interest. A radar such as the APS-44A, which has a pencil beam antenna but is made to scan only horizontally, presents the most difficult problem. In this case, the aircraft's altitude and range (either ground or slant range) will be used to compute the elevation angle to which the antenna must be manually set. (See Fig. 4 and 5). At the longer ranges, the aircraft will stay within the beam for a fairly great distance (see Fig. 6) but correction of elevation angle will still be made to optimize the operating condition.

A short study was made to determine the effect of detecting either of the aircraft on the sides of the radar's antenna beam instead of on the axis. Several beam shapes were studied. It appears that, in all cases, serious erroneous deductions could be drawn from the resultant data on relative detection range. For example, consider a pencil beam fixed at some elevation angle and the two aircraft (standard and modified T-33 to be called T-33 and MT-33 respectively henceforth in this paper) flying toward the radar at the same constant altitude. Assume the T-33 is detected as it passes through the axis of the beam (see Fig. 7). The MT-33, with its lower reflection, will have to be closer to the radar before it can be detected. However, in continuing at the same altitude, it is gradually being illuminated with less radar signal due to the antenna beam's shape. It turns out in most cases that the falloff in illumination is faster than the rise in echo due to the decrease in range, thus the aircraft will

never be seen by the radar. This could lead to the conclusion that the aircraft was truly "radar invisible." On the other hand, assume that the antenna was raised to some elevation angle such that the T-33 was detected by the side of the beam at a certain range. The MT-33 will continue to fly into the beam, thereby being illuminated by an increasingly larger signal while at the same time decreasing in range. This situation would cause the range ratio to be less than the 2:1 expected and could lead to the conclusion that the absorber was poor. A plot of the relative range versus the angle between the aircraft's flight path and the axis of the radar beam is shown in Fig. 8. For simplicity of calculation it was assumed that the MT-33 was detected as it passed through the axis of the beam each time. While these figures are based on the pencil beam case, the same sort of thing would occur for other shaped beams. The conclusion from this study is that the elevation angle of the beam must be varied so that detection takes place when the aircraft is on the nose of the beam.

This measurement technique does not lend itself well to taking data for aspects other than nose, tail and broadside. However, the relative simplicity and flexibility of the technique and the ability to use unmodified radars make it very attractive. It is anticipated that this technique will not only be used when making tests with some WADC radars but also with those of Air Defense Command and other operational groups.

In addition to the tests against the ground radars, it is planned to run relative detection range tests against standard AI and fire control radars. In these tests a fighter aircraft will be vectored toward the standard and modified T-33 aircraft in such a way as to approach from various angles. The relative detection range would be reported by the pilot. It is understood that in such tests nose-on approaches are extremely dangerous and hence would not be attempted. The advantage of this type of testing over the ground radar tests is that some of the aspects above the horizontal plane of the aircraft can be checked. A disadvantage lies in the fact that the pilot has many things to do besides watching the radar, which could cause wider variations in the readings of detection range. Ordinarily this type of test is performed on a

statistical basis which requires a fairly large number of flights. The T-33s under test would fly a straight and level course while the aircraft carrying the measuring radar makes a number of passes at each of the various angles of approach.

The procedure for determining the relative echo signal intensity as a function of aspect angle is shown in Fig. 9. Both aircraft could be made to fly cloverleaf patterns over a check point to eliminate the range effect on echo. The radar antenna would be aimed to put its beam over the check point at the aircraft's altitude. The radar has to be instrumented to record the amplitude of the echo signal as the two aircraft alternate over the check point. By varying the direction of the passes over the check point a plot of relative echo signal versus aspect angle can be obtained.

This technique is probably the best way to evaluate the material since it yields quantitative data and does not depend on judgment as to whether or not a certain-sized blip constitutes detection or not. As was mentioned previously, personnel of WCIRE-5 could make the necessary modifications to radars at WADC. It appears to be simpler and feasible to provide a separate "receiver-recorder" package which can be tied in to any radar system through a change in the microwave "plumbing." This technique will be investigated as soon as a new receiver, currently on order, is received.

There are several possibilities for variations in the above technique. For instance, it is expected that a tracking radar will be used for some of these tests. This radar would continuously track one or the other aircraft as it flew the various patterns. The radar already has an AGC system and it is felt that bringing this voltage out to a recorder would be relatively simple. The fact that this AGC is relatively slow-acting is not a great drawback since the average echo signal differential is of prime importance in these tests.

Another phase of the relative echo signal intensity tests will involve the dynamic air-to-air reflection measurements equipment developed by Dalmo-Victor Corporation under Contract AF33(600)-27570. This equipment is designed to record the echo area of an aircraft as a function of aspect angle to a high degree of accuracy. An "S"

band radar's antenna is slaved to an "X" band tracking radar which is locked on the target under test. The echo area information is gathered by the "S" band gear. The equipment is designed to measure aspect angles accurately and is expected to provide a plot similar to that provided through static techniques. During these flights, the aircraft under test will fly a straight level course while the measuring aircraft will fly around it in various ways to take data as a function of aspect. It is expected that data can be taken over 360 degrees of azimuth and ± 20 degrees in elevation with respect to the target ship. Passes can be made at higher elevation angles but 360 degree azimuth coverage is not expected under these conditions.

Tests to determine the degradation in defensive system performance could vary greatly depending upon the system under test. For instance, it is proposed that standard EW-GCI-AI missions be run against both aircraft to determine the cumulative effect of the absorber upon the intercept probability. The 58th. Air Division, Air Defense Command, has expressed willingness to perform this type of sequential mission. These tests would be performed both with and without simple evasive maneuvers on the part of the MT-33. It has not been determined whether or not any defensive missile systems can be adequately synthesized to yield performance degradation data of this type or even whether or not such tests should be included as part of this program.

The relative effectiveness of improved absorber materials will be tested by replacing the removable sections on the aircraft with the new materials and repeating the relative echo intensity tests as outlined above. Naturally, any such material would be thoroughly tested in the Laboratory before it would warrant any dynamic testing.

It has been suggested by personnel from Hq. ARDC that tests be run to determine the effectiveness of partial absorber coating on reflectivity. Unfortunately, the MT-33 cannot be flown with some of the panels removed. However, partial coating can be simulated by spraying selected sections of the absorber with a coat of strippable plastic and then with a coat of metallic silver paint. This technique has proven very satisfactory in the Laboratory tests. After such an application the relative echo

intensity tests would be rerun. It is felt that such tests can be performed more easily, more quickly and more cheaply through static model techniques which are commonly used by WADC, but dynamic testing as outlined above can be run during the course of the flight testing.

No.

It is expected that there will be some modification to the above plans as the tests progress. These tests are based upon the equipments and personnel available at this time and while no major changes in either are anticipated, the possibility still exists.

The tests with the Air Defense Command will require coordination with their Headquarters at Ent AFB. Personnel of WCLRE-5 will contact them in this regard in the near future. A priority higher than the current 1-B enjoyed by this program would undoubtedly help not only these tests but all the others planned under "Passport Visa."

Appendix A

Pertinent Characteristics of Radars Available for "Passport Visa" Tests

APS-20: search radar with pencil beam

P_T = 750 kw

receiver sensitivity = -102 DBM

frequency = 2880 mc

beamwidth: vertical, 8°; horizontal, 3.5°

antenna scans 360° at 6 rpm

sector scans any 20° to 120° wide sector (variable)

MSQ-1: tracking radar

P_T = 250 kw - 500 kw

receiver sensitivity = -106 DBM

frequency = 2700-2900 mc (tunable)

beamwidth: 3° both planes

tracks at 3 DB points on beam

can give horizontal or vertical polarization

APS-44A: search radar with pencil beam

"X" band portion:

B_T = 500 kw

receiver sensitivity = -100 DBM

frequency = 9375 mc

beamwidth: 1.8° both planes

scans 180° azimuth

sector scan any 30° wide section of basic 180° scan

manual set of tilt from 0° to +5° in elevation

can produce vertical or circular polarization

APS-44A: search radar with pencil beam (continued)

"C" band portion:

P_T = 1.0 megwatt

receiver sensitivity = -100 DBM

frequency = 5280 mc

beamwidth: 2.8° both planes

all other antenna characteristics same as "X" band

FPS-16: precision approach radar

P_T = 45 kw

receiver sensitivity = -88 DBM

frequency = 9080 mc

has 2 antennas:

one scans from -1° to +6° vertically with .5° wide beam in elevation and $\csc^2$ beam in azimuth

the other scans ±10° in azimuth with .5° wide beam in azimuth and $\csc^2$ beam in elevation

rate of scan: 2 scans/antenna/second

receiver alternates between antennas

FPS-6: height finder with nodding beavertail beam (same as MPS-14)

P_T = 5 megwatt

receiver sensitivity = -104 DBM

frequency = 2700-2900 mc

antenna gain: -7400

beamwidth: 3.2° azimuth; 0.95° elevation

antenna sweeps vertically from -2° to +32° at nod rate of 20 to 30 per minute

controlled in azimuth by search radar

APG-37: airborne fire control radar (tracking)

P_T = 200 kw

receiver sensitivity = approx. -95 DBM

frequency = 8500-9250 mc

beamwidth: 4° in both planes

conical scan at 75 cycles/second

TPS-16: airport surveillance radar

P_T = 450 kw

receiver sensitivity = -100 DBM

frequency = 2700-2900 mc

beamwidth: 1.6° in azimuth; csc^2 in vertical plane

antenna scans 360° azimuth at 6 rpm

SCR-584: tracking radar (MSQ-1 is later version)

P_T = 300 kw

receiver sensitivity = -96 DBM

frequency = 2700-2900 mc

beamwidth: 4° in both planes

MSQ-1A: see MSQ-1

MPS-4: height finder with nodding beavertail beam

P_T = 140 kw

receiver sensitivity = -100 DBM

frequency = 6275-6575 mc

antenna beamwidth: 4° azimuth; .8° elevation

nods over any 10° sector from -2° to +20° (sector can be moved during flight)

controlled in azimuth by search radar

TPS-10D: height finder with nodding beavertail beam (same as MPS-8 & FPS-4)

P_T = 250 kw

receiver sensitivity = -100 DBM

frequency = 9200 mc

antenna beamwidth: 2° azimuth; .7° elevation

antenna nods from -2° to +23° at either 30 or 60 times/ minute

MPS-14: see FPS-6

FPS-10: search radar (same as CPS-6B)

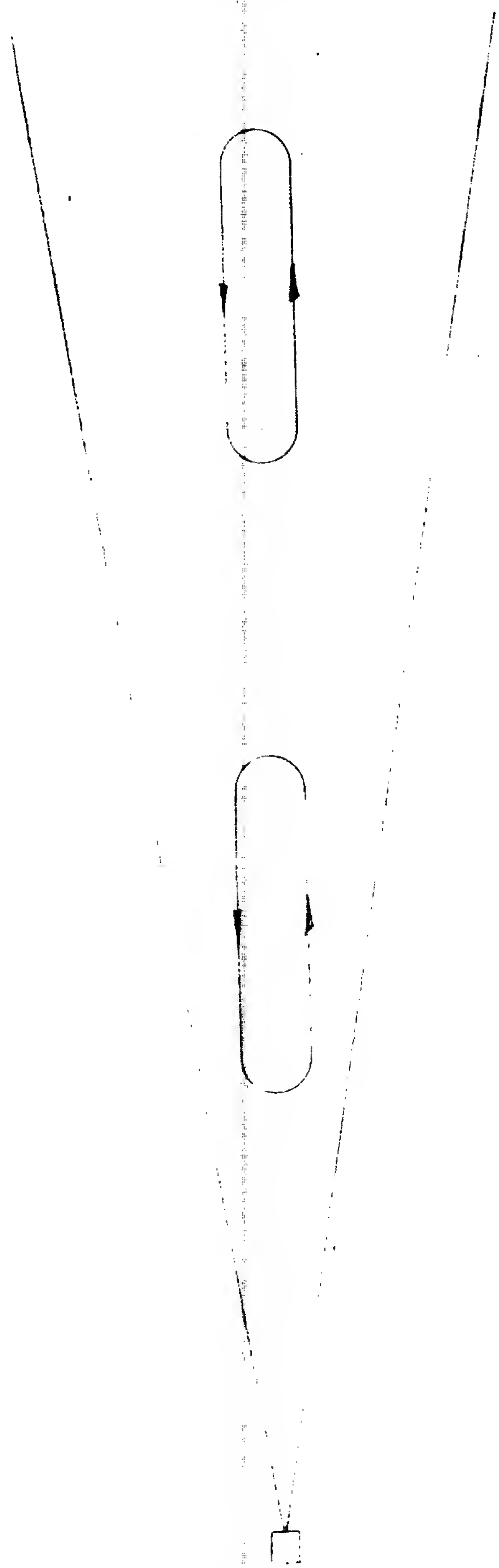
P_T = 1.0 megwatt

receiver sensitivity = approx. -90 DBM

frequency = 2700-2900 mc

antenna beamwidth: 1° azimuth; covers from +2°to +23° elevation

antenna scans at 1/6 rpm



NOSE AND TAIL PASSES

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Fig. 1

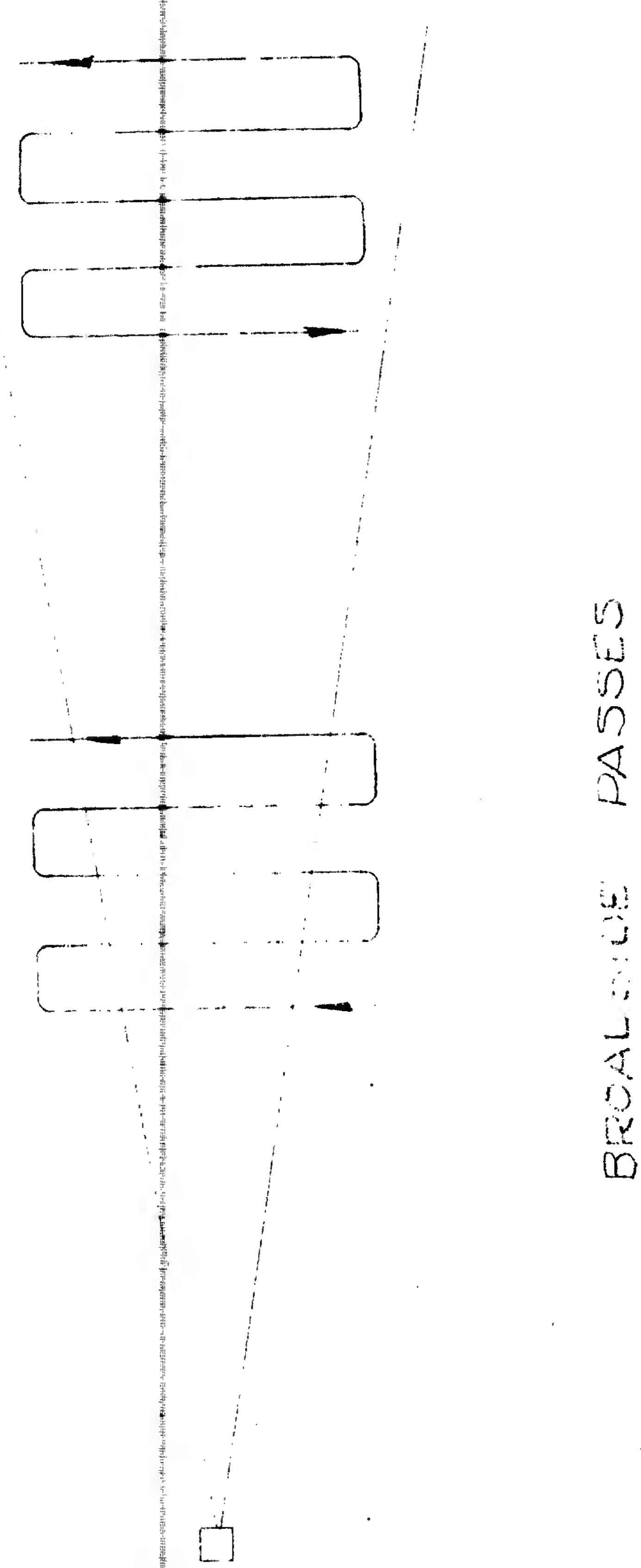

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Fig. 2

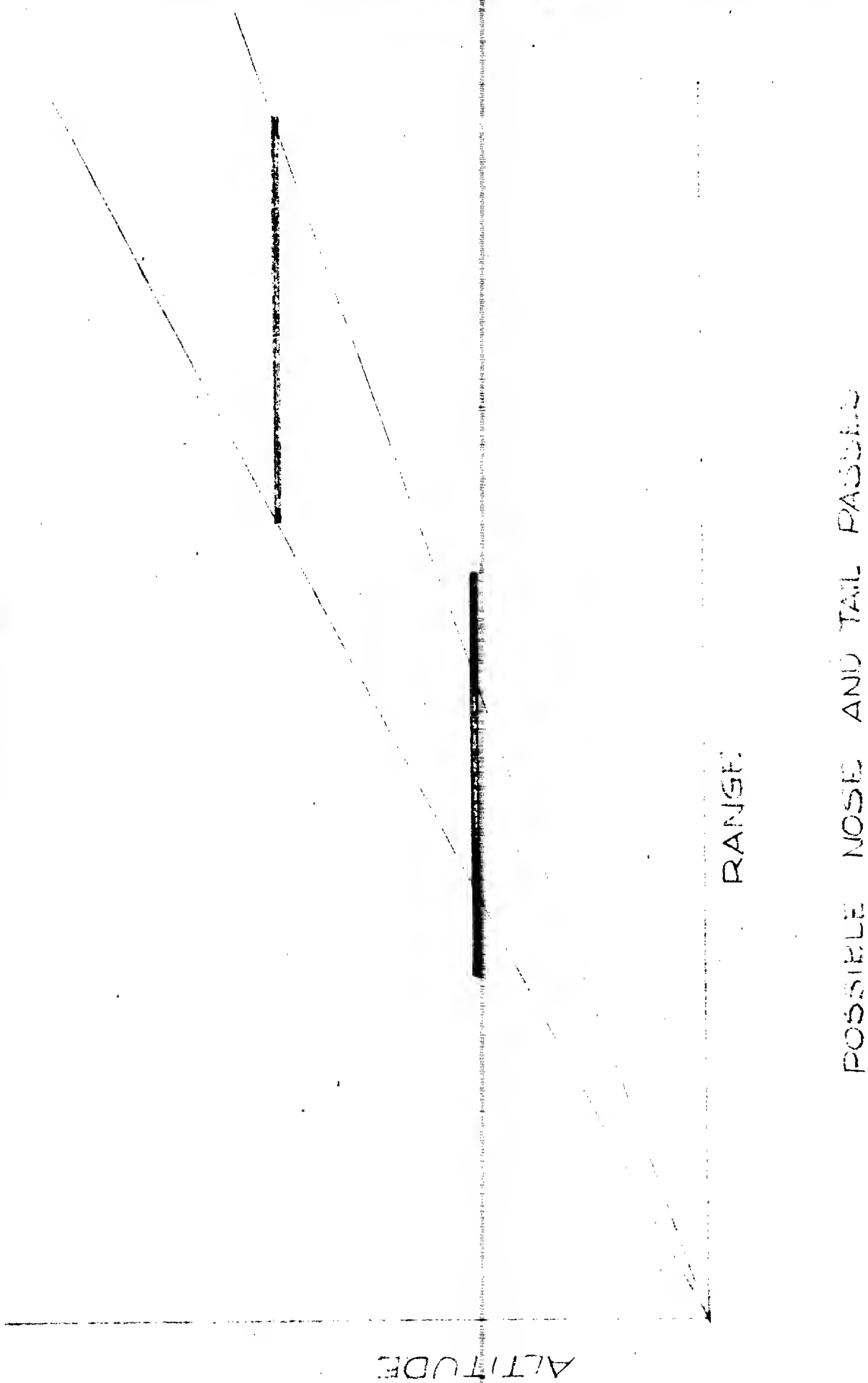

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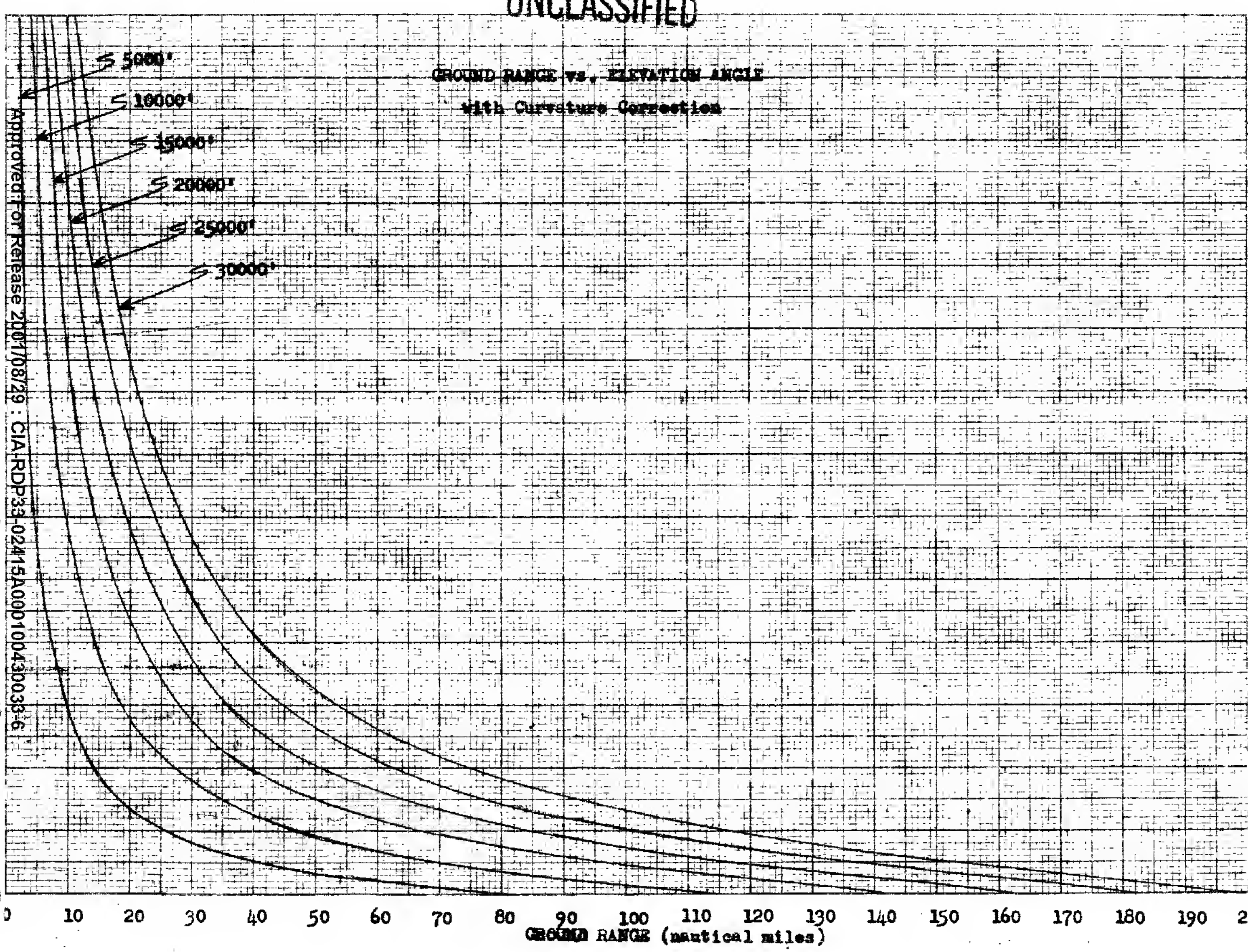
Fig. 3



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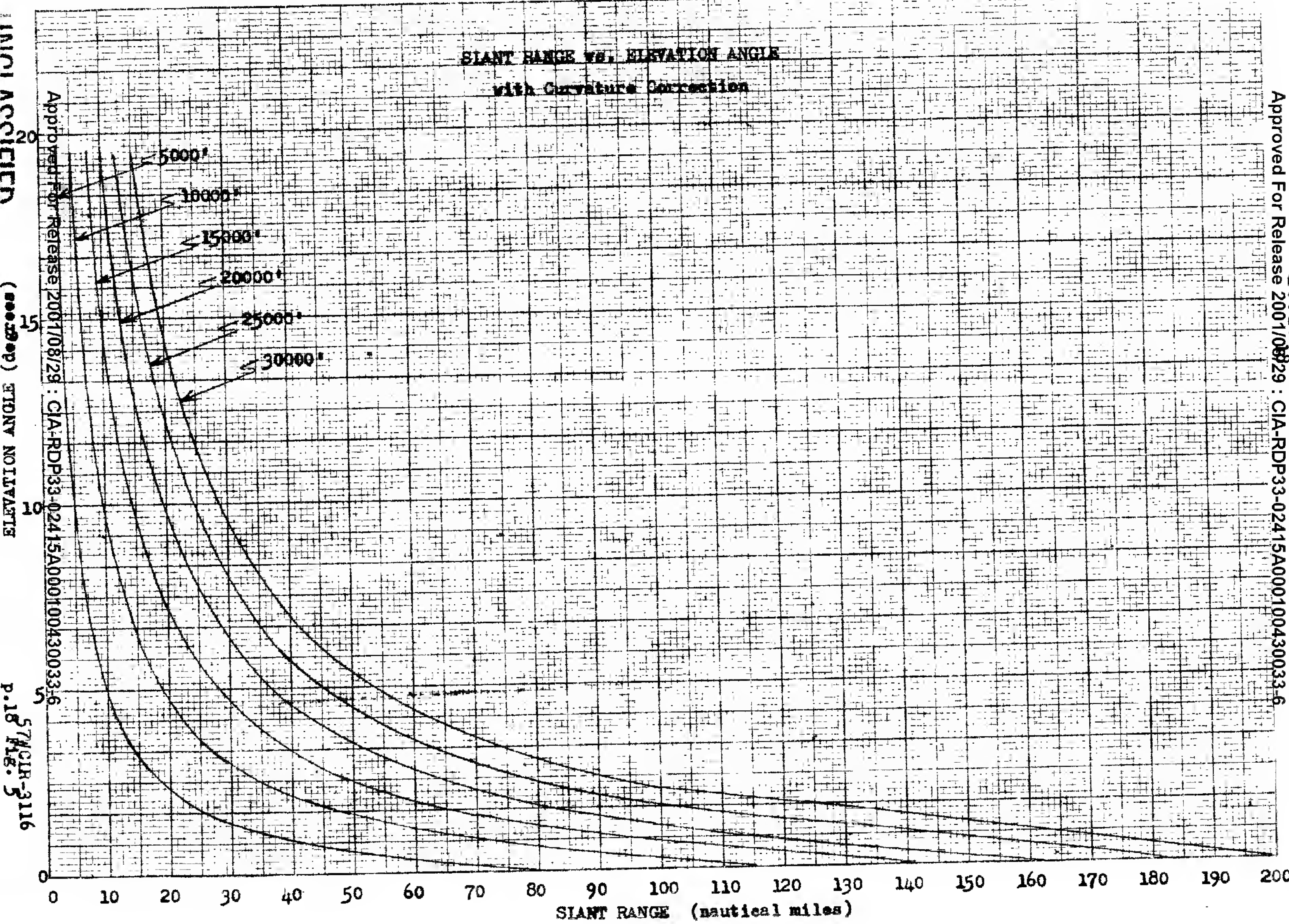
SLANT RANGE vs. ELEVATION ANGLE
with Curvature Correction



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p.18 Fig. 5

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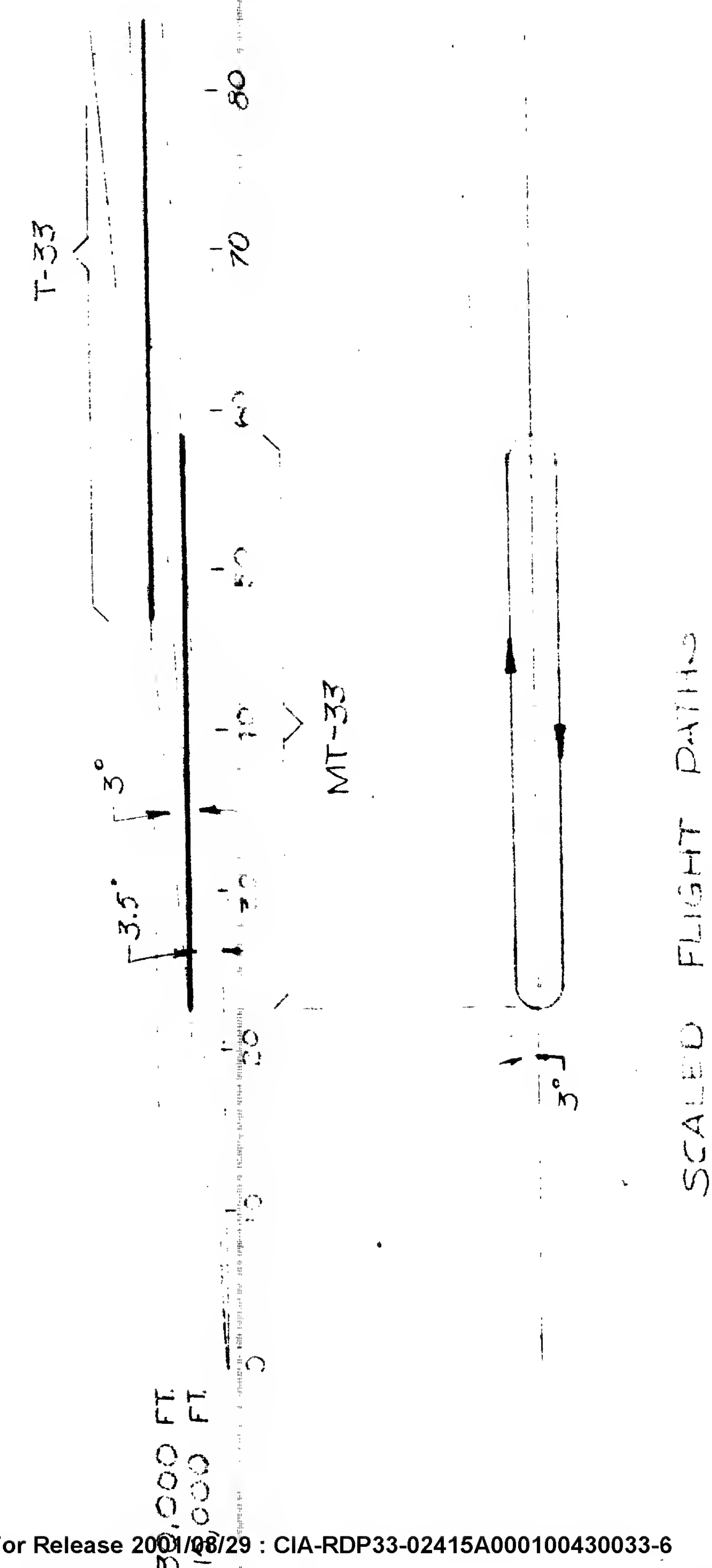

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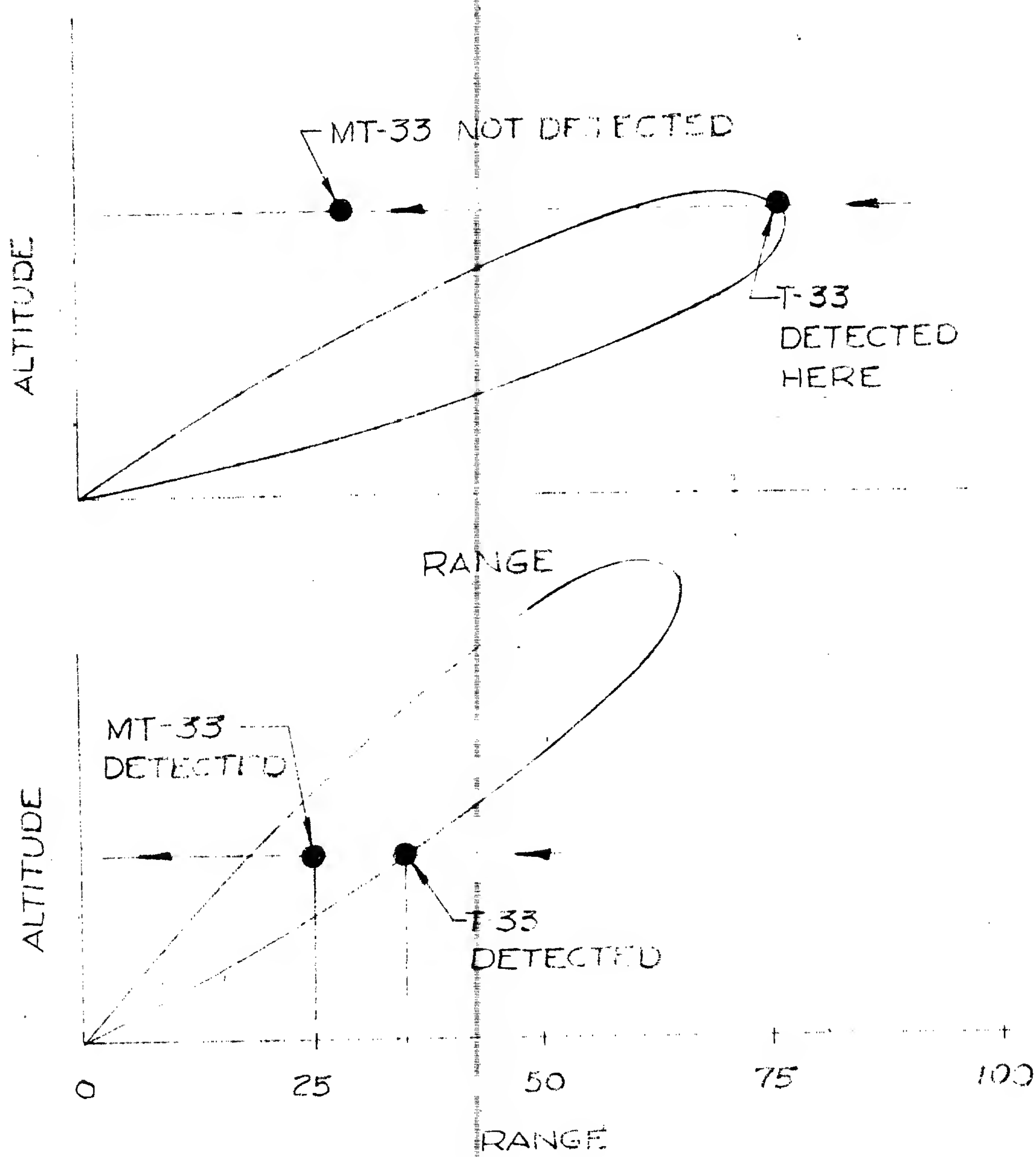
Fig. 6



POSSIBLE RELATIVE DETECTION RANGE ERRORS

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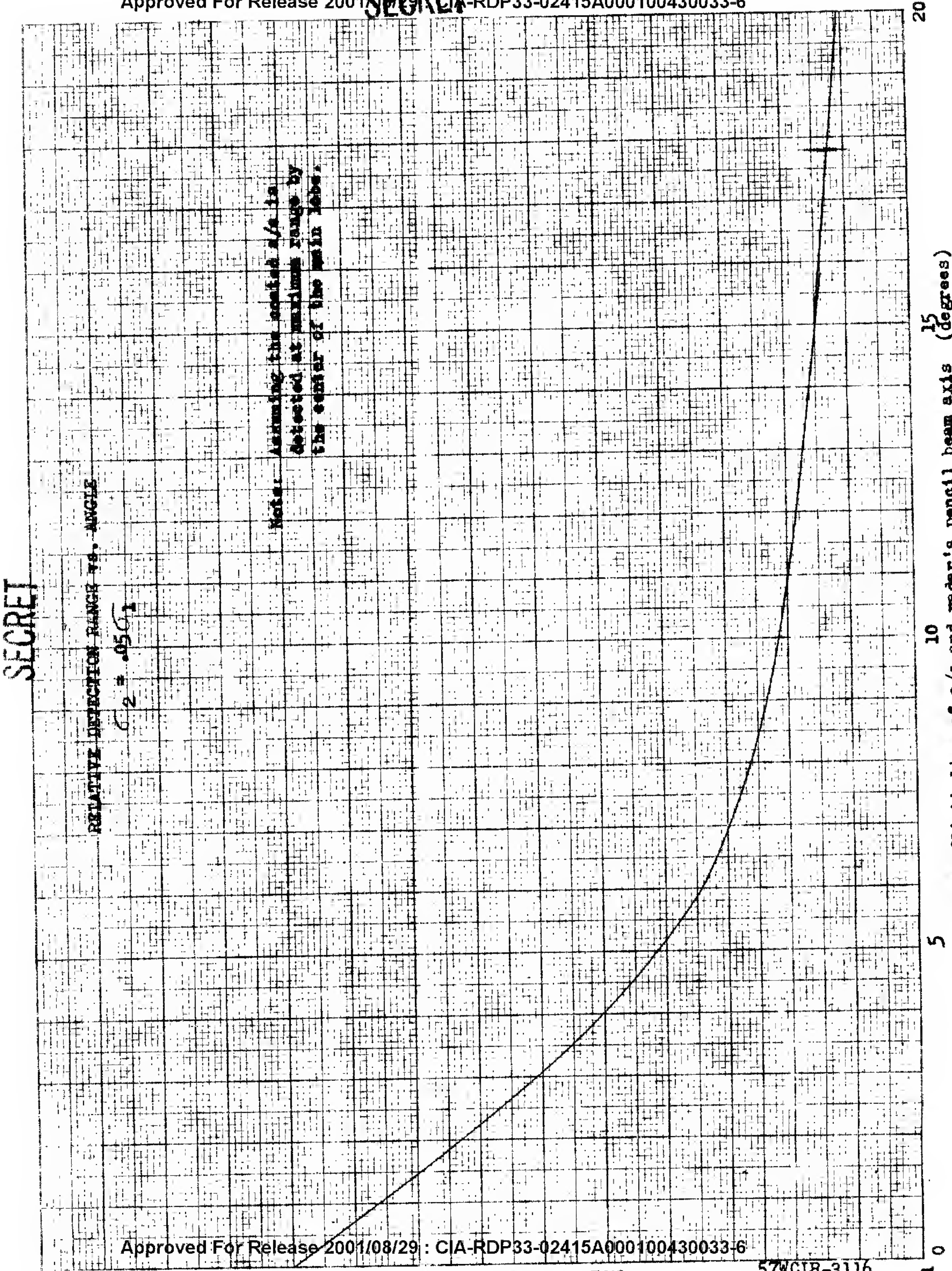

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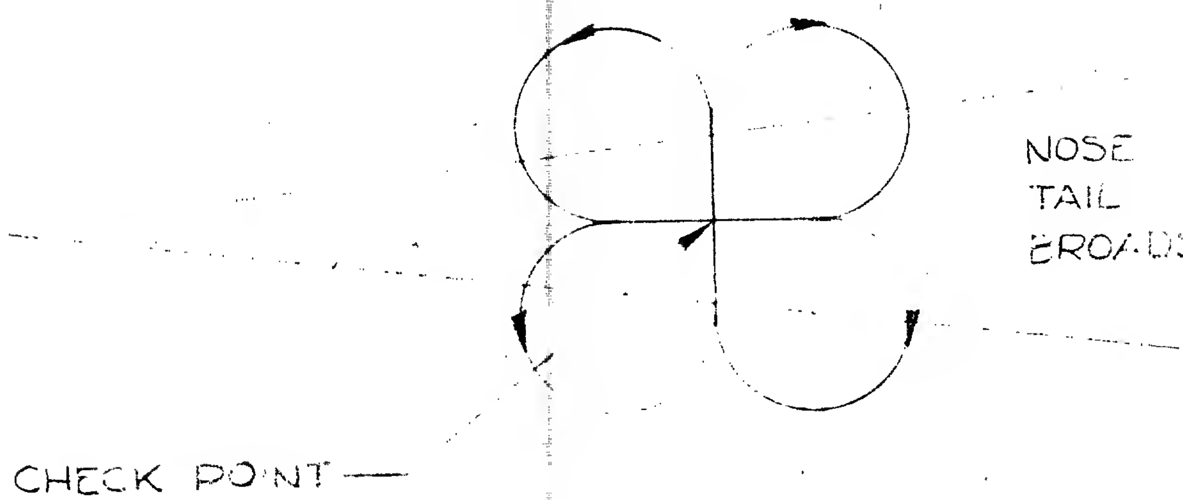
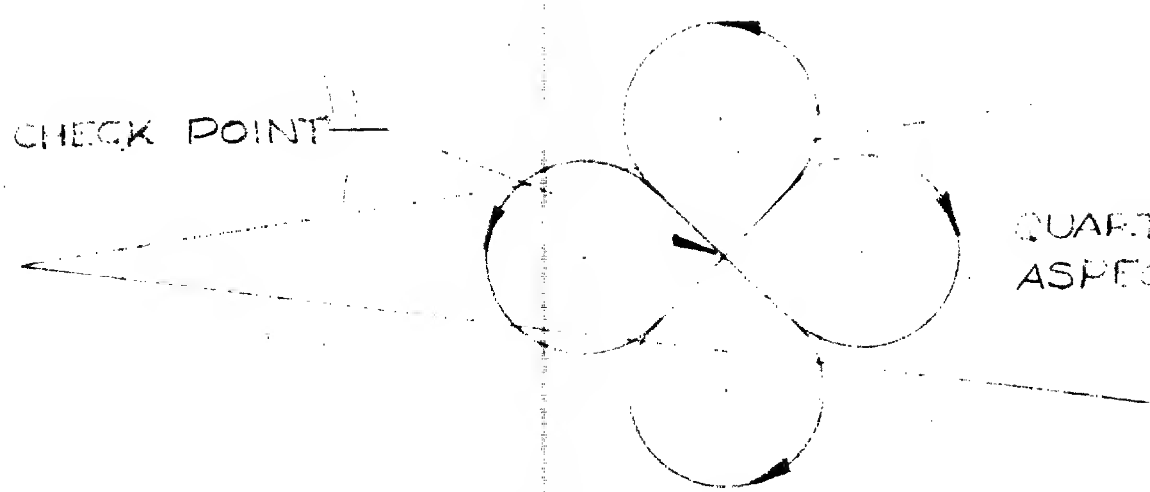
Fig. 8





RELATIVE ECHO INTENSITY FLIGHT PLANS